Express Mail No: <u>EV305339417US</u>

UNITED STATES PATENT APPLICATION

FOR

**TECHNIQUES TO REDUCE ECHO**

Inventors:

Vijayakrishna P. Guduru

Hyung W. Paik

Prepared by:

BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP
12400 Wilshire Boulevard, Seventh Floor
Los Angeles, CA 90025-1030
(408) 720-8300

# TECHNIQUES TO REDUCE ECHO

Vijayakrishna P. Guduru

Hyung W. Paik

## Field

[0001]    The subject matter disclosed herein generally relates to techniques to control echo.

## Description of Related Art

[0002]    It is well known that in many communications systems, transmission of signals between a transmitter and a receiver generates noise arising from signal reflection from at least impedance mismatching and interface points (so called "echo"). Consequently, echo often corrupts the signal quality of a transmitted signal so that the receiver cannot accurately reproduce the signal. Echo cancellers can be used to control echo.

## Brief Description of the Drawings

[0003]    FIG. 1 depicts in block diagram format a communications system;

[0004]    FIG. 2 depicts one possible implementation of an echo canceller in accordance with an embodiment of the present invention;

[0005]    FIG. 3 depicts an example implementation of an adaptive filter in accordance with an embodiment of the present invention; and

[0006]        FIG. 4 depicts a process in accordance with an embodiment of the present

invention.

[0007]        Note that use of the same reference numbers in different figures indicates the

same or like elements.


## Detailed Description

[0008]        FIG. 1 depicts in block diagram format a communications system 5. Near end

communications device 10 and far end communications device 20 may communicate using a

signal propagation medium such as a full duplex line, twisted pair telephone line, coaxial cable,

fiber optic cable, or wireless techniques. For example, near end communications device 10 may

provide communications capabilities of a telephone such as a speaker to generate sound based on

a signal received from far end communications device 20 and also include a microphone to

receive sound from a user of near end communications device 10. Near end communications

device 10 may use some embodiments of the present invention. For example, far end

communications device 20 may provide communications capabilities of a central office in a

telephonic communications system.

[0009]        FIG. 2 depicts one possible implementation of echo canceller 200 in accordance

with an embodiment of the present invention, although other implementations may be used.

Echo canceller 200 may include controller 210, fixed filter 212, adaptive filter 214, coefficient

storage 216, and comfort noise generator 218. A far end signal can be a signal transmitted by the

device that uses echo canceller 200 (e.g., a data or voice signal) to a far end modem. A near end

signal can be a signal received from a far-end modem (e.g., a data or voice signal) which may

include echo attributable to the far end signal. **[Hardwired, software, or firmware]**

3

[0010]     Echo canceller 200 may perform echo cancellation on sub-blocks. For

example, a block may include multiple sub-blocks, where each sub-block includes one or

more samples of a signal (e.g., near end signal or far end signal). The time duration of

each sub-block may be the same. For example, samples may be based on a sample rate of 8

kilohertz (kHz), although other sample rates may be used. Echo canceller 200 may process

the same time portion of one or more sub-blocks of the near end signal more than once

without interrupting real-time audio reproduction of the near end signal. For example, the

same time portion of the near end signal may be provided to each of controller 210, fixed

filter 212, adaptive filter 214, and comfort noise generator 218.

[0011]     Echo canceller 200 may be implemented as any or a combination of hardwired

logic, software stored by a memory device and executed by a microprocessor, firmware, an

application specific integrated circuit (ASIC), and/or a field programmable gate array (FPGA).

[0012]     Controller 210 may receive a near end signal and far end signal. For example,

controller 210 may receive the same time portion of the far end signal as that of the near

end signal. Based on energy characteristics of the near and far end signals, controller 210 may

determine whether the current time portion of the near end signal is to be processed by fixed

filter 212 or adaptive filter 214, or no filtering is to be performed on the current time portion of

the near end signal by fixed filter 212 or adaptive filter 214. Controller 210 may control whether

the fixed filter 212 or adaptive filter 214 is to process the near end signal by use of respective

ENABLE1 and ENABLE2 signals.

[0013]     Coefficient storage 216 may store filter tap coefficients used by fixed filter 212

and adaptive filter 214. The coefficients may be initialized to zero. For example, adaptive filter

214 may store coefficients into and retrieve coefficients from coefficient storage 216. For

example, fixed filter 212 may retrieve coefficients from coefficient memory 216. For example, adaptive filter 214 may provide coefficients to coefficient storage 216 for use by fixed filter 212.

[0014]     Fixed filter 212 may perform finite impulse response (FIR) filtering relevant sub-blocks of the near end signal. The number of filter taps of fixed filter 212 may be based on a time to receive a reflected signal in response to a signal transmitted through a signal propagation medium. Fixed filter 212 may retrieve its filter tap coefficients from coefficient storage 216 and use the coefficients to process the near end signal.

[0015]     Adaptive filter 214 may perform adaptive FIR filtering on the near end signal. Adaptive filter 214 may adjust filter tap coefficients every sample. Adaptive filter 214 may use a recursive normalized least mean square (LMS) algorithm to update coefficients based on processing of the near end signal. Adaptive filter 214 may track variations in the characteristics of the signal propagation medium. In one implementation, if MIPS (million instructions per second) speed is insufficient, adaptive filter 214 may process every other relevant sub-block of the near end signal. If MIPS speed is sufficient, then adaptive filter 214 may process every relevant sub-block of the near end signal. One implementation of adaptive filter 214 may include a background filter and foreground filter.

[0016]     For example, FIG. 3 depicts one possible implementation of adaptive filter 214, but not the only possible implementation. One implementation of adaptive filter 214 includes background adaptive filter 310, background filter memory 315, and foreground adaptive filter 320. In one implementation, foreground adaptive filter 320 processes a current time portion of the near end signal and provides the output from adaptive filter 214. In one implementation, while foreground adaptive filter 320 processes and outputs a current time portion of the near end signal, background adaptive filter 310 processes the same time portion of

the near end signal and updates coefficients using the LMS algorithm based on processing of the near end signal.

[0017]     Foreground adaptive filter 320 may perform a simple FIR filtering technique on the near end signal. The number of filter taps of the foreground adaptive filter 320 may be based on a time to receive a reflected signal in response to a signal transmitted through a signal propagation medium. Foreground adaptive filter 320 may retrieve filter tap coefficients from coefficient storage 216 and use the coefficients to process the near end signal.

[0018]     Background adaptive filter 310 may perform adaptive FIR filtering on the near end signal. In one implementation, background adaptive filter coefficients may be initialized to zero. Background adaptive filter 310 may adjust its filter tap coefficients every sample of the near end signal. Background adaptive filter 310 may use an LMS algorithm to update coefficients based on processing of the near end signal. Background adaptive filter 310 may store coefficients into background filter memory 315. Background filter memory 315 may store coefficients into coefficient storage 216. For example, foreground adaptive filter 320 may retrieve coefficients from coefficient storage 216 that may be provided by background filter memory 315.

[0019]     Based on the noise present in the current time portion of the near end signal processed by fixed filter 212 or adaptive filter 214 or not processed by fixed filter 212 or adaptive filter 214, comfort noise generator 218 may replace such time portion of the near end signal with comfort noise. Comfort noise may be a similar noise level as that in the current time portion of the near end signal. The time portion of the near end signal provided by comfort noise generator 218 (whether replaced by comfort noise or not) may be provided for audible performance.

[0020]     FIG. 4 depicts an embodiment of the present invention in process 400. For example, an echo canceller may utilize the process 400 to reduce echo noise in near end signals. The echo canceller may utilize a fixed filter, adaptive filter, coefficient memory, and comfort noise generator. In one implementation, process 400 may process a same time portion of each of the near end and far end signals, where each portion is one or more subblocks.

[0021]     Action 401 may include initializing coefficients used by the fixed filter and the adaptive filter to zero. Action 403 may include reading a block of the near end signal. A block may include multiple sub-blocks, where each sub-block includes one or more samples of the near end signal. Action 405 may include detecting an echo canceller disabling tone in the read portion of the near end signal (for example at 2.1 kHz) in compliance, for example, with ITU-T G.168 (2000). If an echo canceller disabling tone is detected, then action 407 may follow action 405. If an echo canceller disabling tone is not detected, then action 410 may follow action 405.

[0022]     Action 407 may include transferring the block of the near end signal without echo cancellation processing. Action 403 may follow action 407.

[0023]     Action 410 may include resetting a current subblock counter variable (variable SubBlockcnt) to zero. Action 415 may include determining whether the current subblock counter variable is within a range of subblocks numbered within a block (variable MaxCnt). If the current subblock counter variable is within a range of subblocks numbered within a block, then action 420 may follow action 415. If the current subblock counter variable is not within a range of subblocks numbered within a block, then action 403 may follow action 415.

[0024]     Action 420 may include detecting energy levels of the current portion of the far end signal and the current portion of the near end signal. Action 425 may include determining

whether a ratio of the current portion of the far end energy signal over the current portion of the near end signal energy is sufficiently high. If the ratio is not sufficiently high, then action 430 may follow action 425. If the ratio is sufficiently high, then action 435 may follow action 425.

[0025]     Action 430 may include transferring the current portion of the near end signal without filtering by a fixed filter or adaptive filter. Action 450 may follow action 430.

[0026]     Action 435 may include determining whether energy levels of the following signals each exceed the same or different threshold(s): (a) the current portion of the far end signal and (b) the current portion of the near end signal. Action 440 may follow action 435 if both (a) and (b) are sufficiently high. Action 445 may follow action 435 if either (a) or (b) is not sufficiently high.

[0027]     Action 440 may include using a foreground component of the adaptive filter to process the current portion of the near end signal. Action 450 may follow action 440.

[0028]     Action 445 may include using the fixed filter to process the current portion of the near end signal. Action 450 may follow action 445.

[0029]     Action 450 may include determining whether ERLE (defined below) is equal to or greater than a threshold. In action 450, ERLE may be defined as:

energy in current portion of near end signal / energy in the residual signal, where the residual signal is the echo cancelled near end signal (i.e., after processing in action 440 or 445) or the near end signal after transfer by action 430.

If the ERLE is equal to or greater than the threshold, then action 455 may follow action 450. If the ERLE is less than the threshold, then action 460 may follow action 450.

8

**[0030]** Action 455 may include determining filter tap coefficients by utilizing a background component of the adaptive filter to process the current portion of the near end signal (provided from action 430, 440, or 445) and allowing the background adaptive filter to adjust coefficients based on processing of such current portion of the near end signal. Action 457 may follow action 455.

**[0031]** Action 457 may include determining whether variable ERLE2 is equal to or greater than a threshold, where ERLE2 is defined as:

energy in current portion of near end signal / energy in current portion of near end signal after processing by background adaptive filter in action 455.

If the ERLE2 is equal to or greater than the threshold, then action 460 may follow action 457. If the ERLE2 is less than the threshold, then action 459 may follow action 457. For example, the threshold used in action 450 may be different from that used in action 457.

**[0032]** Action 459 may include storing filter tap coefficients determined after processing of the current portion of the near end signal by the background adaptive filter in action 455 to coefficient memory so that such coefficients may be used by the foreground adaptive filter (e.g., in a next operation of action 440) or the fixed filter (e.g., in a next operation of action 445). Action 460 may follow action 459.

**[0033]** Action 460 may include selectively replacing the current portion of the near end signal processed by either the adaptive filter (action 440) or fixed filter (action 445) or transferred without processing (action 430) with comfort noise based on energy level of the residual signal and energy level of the near end signal. The current portion of the near end signal transferred from action 460 may be audibly reproduced for example, by an audio speaker.

[0034]     Action 465 may include increasing a current subblock count. Action 415 may follow action 465.


## Modifications

[0035]     The drawings and the forgoing description gave examples of the present invention. The scope of the present invention, however, is by no means limited by these specific examples. Numerous variations, whether explicitly given in the specification or not, such as differences in structure, dimension, and use of material, are possible. The scope of the invention is at least as broad as given by the following claims.